South Carolina Mobile Broadband Performance Study:

A more precise view of mobile broadband availability and reliability in South Carolina

CostQuest Associates

October 25, 2016

Introduction

Drive testing of mobile networks in the U.S. has generally been focused on metropolitan areas and primary roadways. Given the lack of data on service availability and broadband speeds, this initiative presented a first-step opportunity to inform the discussion.

- CostQuest Associates was asked by U.S. Cellular to independently assess the ground realities of availability and speeds of mobile broadband in South Carolina.
- CostQuest developed a plan and drive test scenarios for assessing mobile broadband and retained the services of RootMetrics® to conduct the drive tests and deliver data.
- The report presents a high-level overview of multiple efforts to gather and benchmark data that will hopefully support a better understanding of customer experience with mobile broadband across varied geographies.

U.S. Cellular was not involved in any aspect of the design or presentation of results.

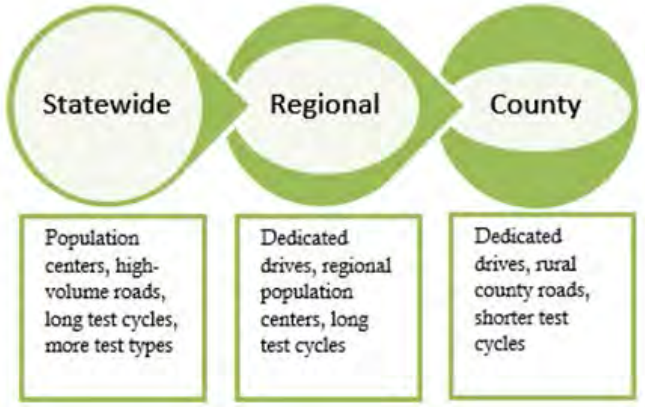
Approach

Overview of Assessment Efforts

RootMetrics® was asked to perform dedicated drive testing to assess availability and throughput of mobile broadband for two specific areas in South Carolina for the four largest carriers serving South Carolina, AT&T, Sprint, T-Mobile, and Verizon. Tests were aggregated for all carriers.

Three drive test studies were conducted.

- The first study was conducted independently by RootMetrics® as part of a greater project aimed at measuring mobile broadband speeds and availability in **more populated centers and heavily-traveled roads across South Carolina.**
- The second study was conducted under the direction of CostQuest and **focused on regional coverage away from metropolitan centers.**
- The third study, also directed by CostQuest, was a more thorough benchmarking project **concentrated on rural roads in just one county** within the same region in southeast South Carolina as the second effort.



Approach

Study 1 – South Carolina Statewide Non-Rural Benchmarking

Description: An assessment of mobile performance in major cities and towns across the entirety of South Carolina, and the roads connecting them.

Carriers Benchmarked: AT&T, Sprint, T-Mobile and Verizon

Dates: March 12, 2016 – March 17, 2016

Test Cycle: 7.5 minutes between tests

Total Test Points: 5,817

Approach

Study 2 – Regional Benchmarking in SE South Carolina

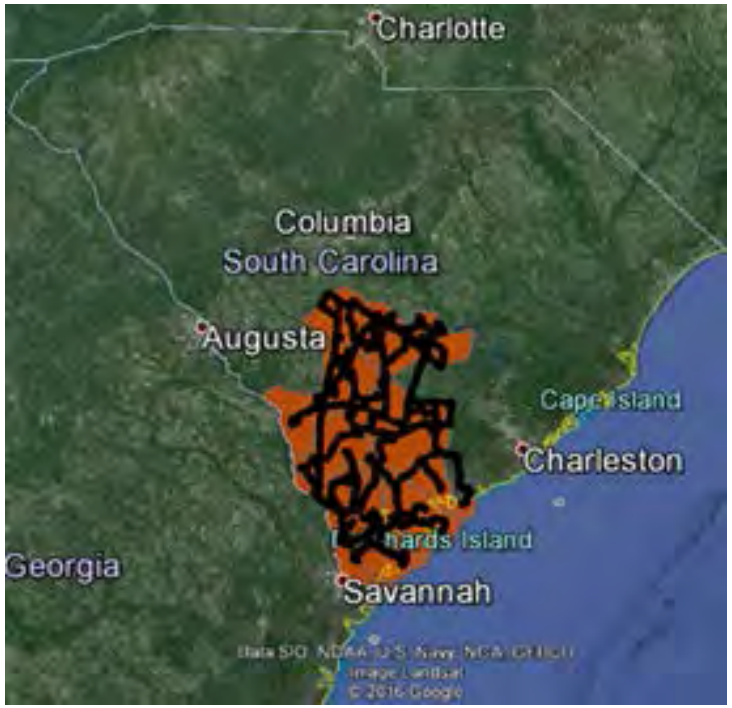
Description: An assessment of mobile performance along major roads in seven counties in the southeastern portion of South Carolina.

Carriers Benchmarked: AT&T, Sprint, T-Mobile and Verizon

Dates: May 2, 2016 – May 6, 2016

Test Cycle: 7.5 minutes between tests

Total Test Points: 4,086



Approach

Study 3 – Rural County Benchmarking in Orangeburg County

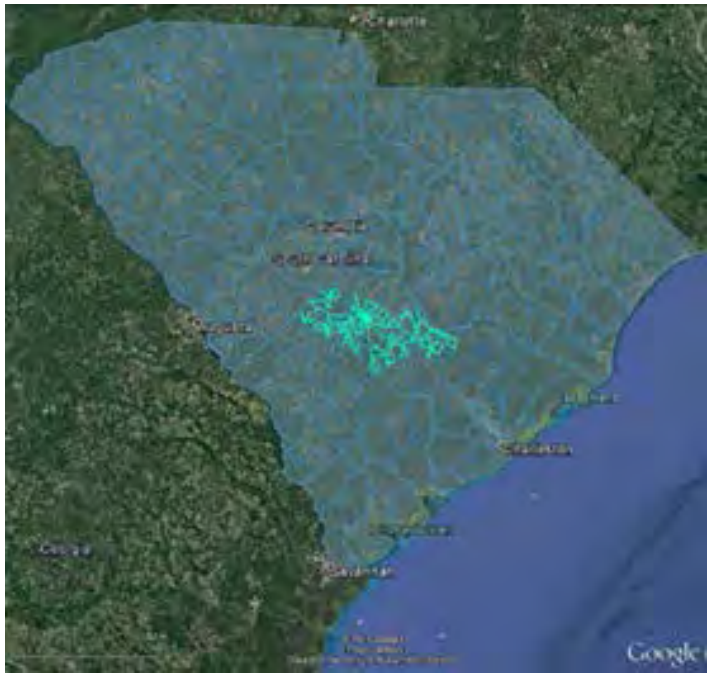
Description: An assessment of mobile performance on rural roads in a largely rural county in southeastern South Carolina.

Carriers Benchmarked: AT&T, Sprint, T-Mobile and Verizon

Dates: June 30, 2016 – July 2, 2016

Test Cycle: 1.5 minutes between tests

Total Test Points: 9,993



Methodology

Overview of Drive Testing Methodology

RootMetrics® pairs engineering expertise with statistical methodologies to design network performance tests, collect data on mobile network performance that reflects a consumer's experience, and employ statistical techniques to determine results.

- The RootMetrics® **testing methodology represents the consumer experience of downloading and uploading data**, among other network activities. Employees of RootMetrics® called Scouters collect test samples.
- **Mobile performance testing is conducted with a proprietary application that measures network performance across mobile network operators simultaneously.** The application is installed and run on advanced off-the-shelf smartphones available to the public at the time of testing.
- **The application focuses its testing around data (download & upload throughput testing).** To evaluate download and upload throughput performance, the RootMetrics® testing application attempts to open and maintain 4 simultaneous HTTP connections to measure the total bytes transferred during the test period. Download and upload throughput reliability and speed are measured during testing.
- **Performance is measured while driving.** Before collecting samples, Scouters complete a pre-test checklist to ensure that all testing equipment is configured and operating correctly. All data is sent to secure servers at RootMetrics® to be processed, aggregated, and analyzed.
- Typically, drive tests are conducted along freeways, major arterials, and residential streets where the population within a market generally lives and travels. However, for this effort, **drive testing was done outside of metropolitan areas and on rural roads as well.**
- **Timing of the data collection period is scheduled to measure performance during representative usage periods.** Therefore, testing is not conducted during major holidays, extreme weather, or during periods of significant population migration effects.

Summary of Results

- **Network reliability differs a great deal inside and outside of Census Designated Places (cities and towns).** Successful connection rates and throughput speeds are generally lower outside of city and town boundary limits.

- **Network reliability across road classifications differs a great deal** as well. Connection rates, signal strength and throughput are all lower on roads that are not within primary travel corridors between population centers.

- **Throughput speeds are generally much lower in areas with lower population density.**

- **The FCC's Form 477 data on mobile network availability, while helpful when trying to understand general presence of mobile providers, does not accurately represent customer experience with respect to access and use of networks.** Many areas that are shown as served by mobile providers in the 477 data are either completely unserved or served at speeds below what would be reasonably considered as broadband (4Mbps down).

Summary of Results

Network reliability differs a great deal inside and outside of Census Designated Places (cities and towns). Successful connection rates, signal strength and throughput speeds are generally lower outside of city and town boundary limits.

Access to the Network (connections with ability to perform a task)

Access to Network	STUDY 1 – SOUTH CAROLINA STATEWIDE NON-RURAL BENCHMARKING	STUDY 2 – REGIONAL BENCHMARKING IN SE SOUTH CAROLINA	STUDY 3 – RURAL COUNTY BENCHMARKING IN ORANGEBURG COUNTY	GRAND TOTAL
Tests Within CDP Boundaries	97%	91%	87%	92%
Tests Outside of CDP Boundaries	91%	78%	73%	77%
Grand Total	94%	81%	76%	82%

Signal Strength

Average Signal Strength in dBm	STUDY 1 – SOUTH CAROLINA STATEWIDE NON-RURAL BENCHMARKING	STUDY 2 – REGIONAL BENCHMARKING IN SE SOUTH CAROLINA	STUDY 3 – RURAL COUNTY BENCHMARKING IN ORANGEBURG COUNTY	GRAND TOTAL
Tests Within CDP Boundaries	-98.6	-101.5	-96.9	-98.4
Tests Outside of CDP Boundaries	-101.1	-105.1	-105.7	-104.6
Grand Total	-99.6	-104.2	-103.4	-102.4

Summary of Results

Network reliability across road classifications differs a great deal as well. Connection rates, signal strength and throughput are all lower on roads that are not within primary travel corridors between population centers.

Connections to the Network

Road Classification Code	Percent Successful Connections
S1100	90%
S1200	63%
S1400	56%
Other Roads (S1740, S1780, S1630, S1640)	82%

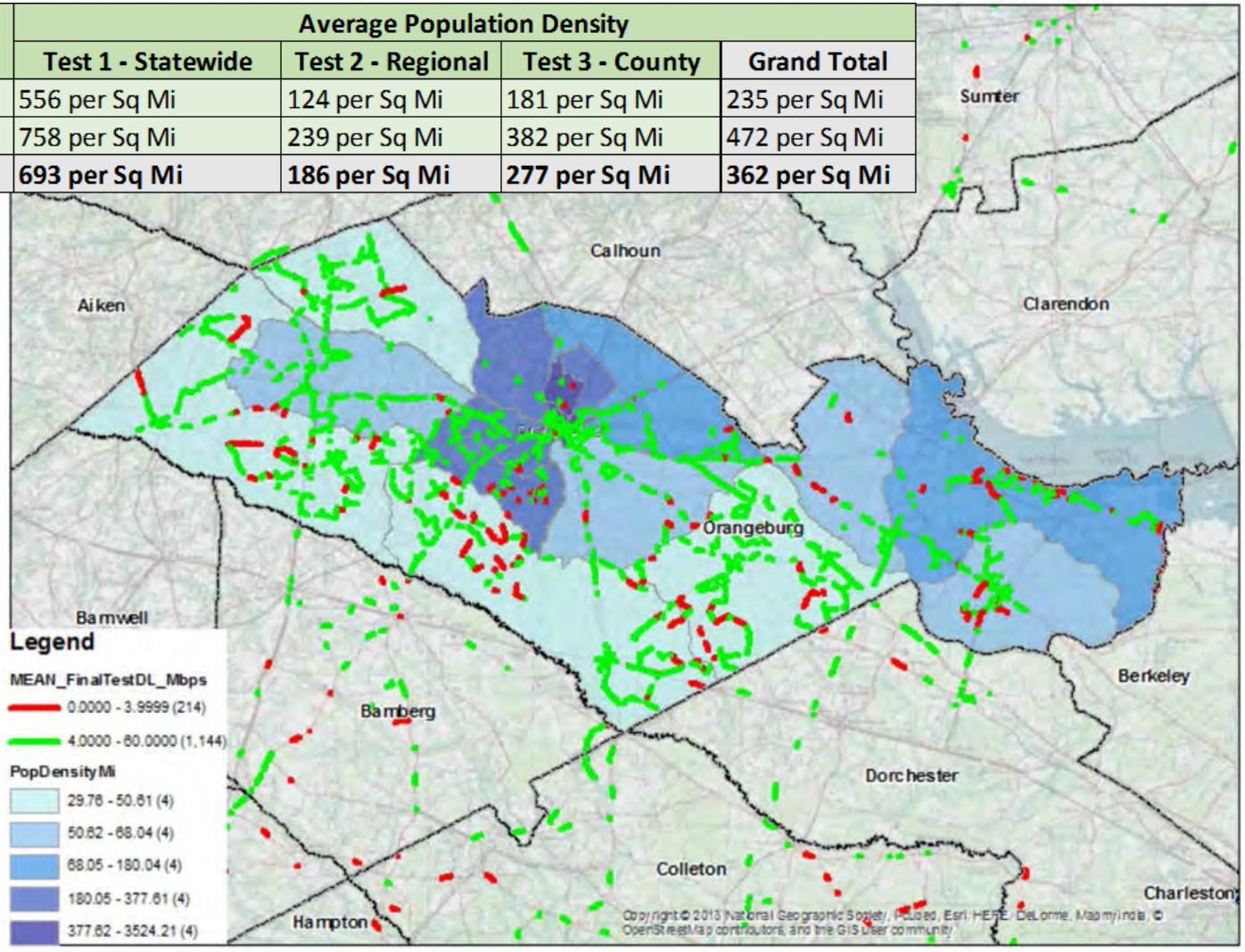
Download Speeds

City/Town or Between	Road Class	Total Download Tests	Total Tests w/ Speeds < 4Mbps (Down)	Percent Tests w/ Speeds < 4Mbps (Down)
Tests Inside City/Town Boundaries (CDP)	S1100	48	18	38%
	S1200	1,432	314	22%
	S1400	1,823	420	23%
	Other Roads	41	14	34%
	All Roads	3,344	766	23%
Tests Outside City/Town Boundaries (CDP)	S1100	255	54	21%
	S1200	2,652	948	36%
	S1400	3,612	1,551	43%
	Other Roads	67	24	36%
	All Roads	6,586	2,577	39%

Summary of Results

Throughput speeds are generally much lower in areas with lower population density.

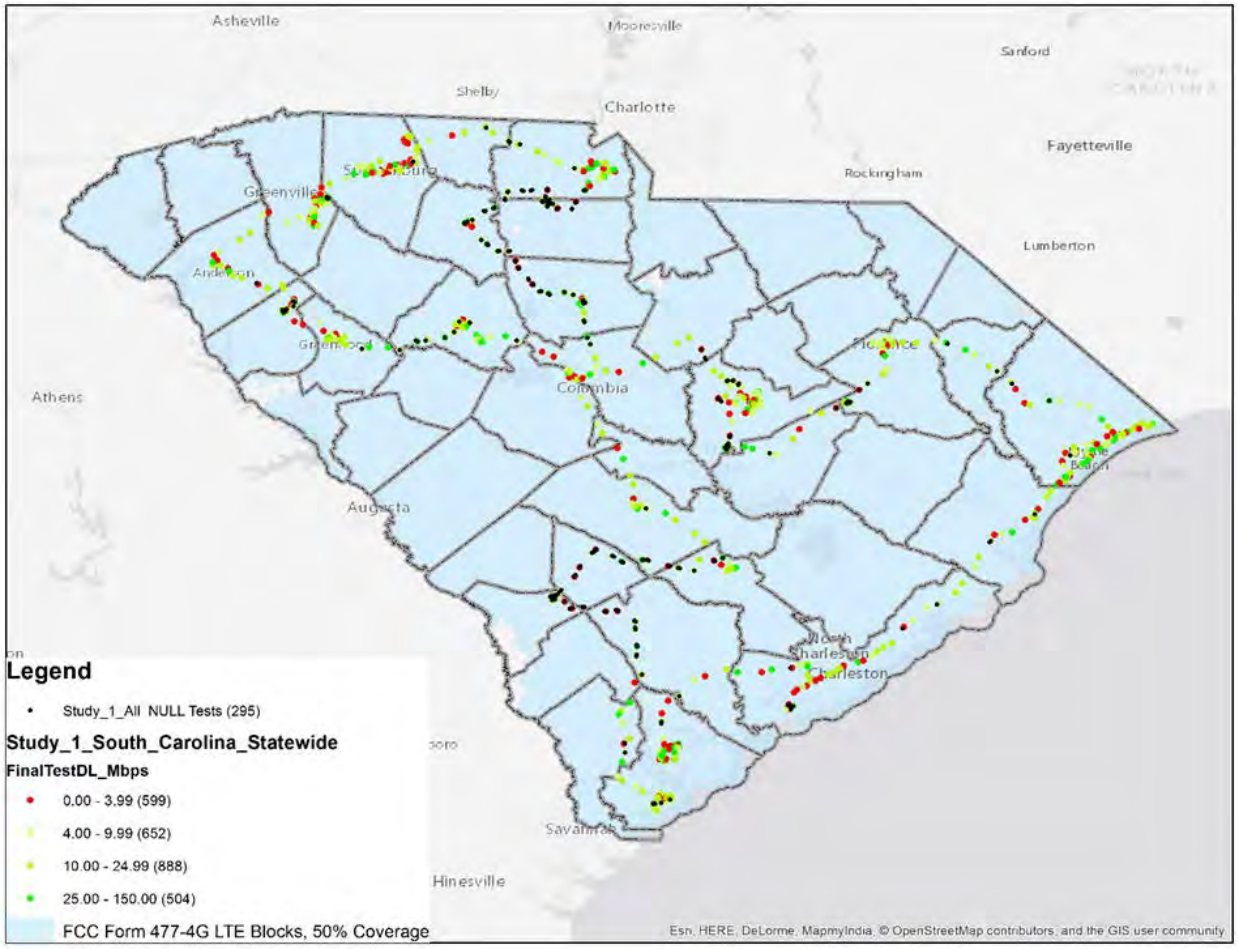
Speed Test Results	Average Population Density			
	Test 1 - Statewide	Test 2 - Regional	Test 3 - County	Grand Total
Less than 4Mbps Down	556 per Sq Mi	124 per Sq Mi	181 per Sq Mi	235 per Sq Mi
Greater than 4Mbps Down	758 per Sq Mi	239 per Sq Mi	382 per Sq Mi	472 per Sq Mi
All Tests	**693 per Sq Mi**	**186 per Sq Mi**	**277 per Sq Mi**	**362 per Sq Mi**



Summary of Results

The FCC's Form 477 data on mobile network availability, while helpful when trying to understand general presence of mobile providers, does not accurately represent customer experience with respect to access and use of networks.

Many areas that are shown as served by mobile providers in the 477 data are either completely unserved or served at speeds below what would be reasonably considered as broadband (4Mbps down).



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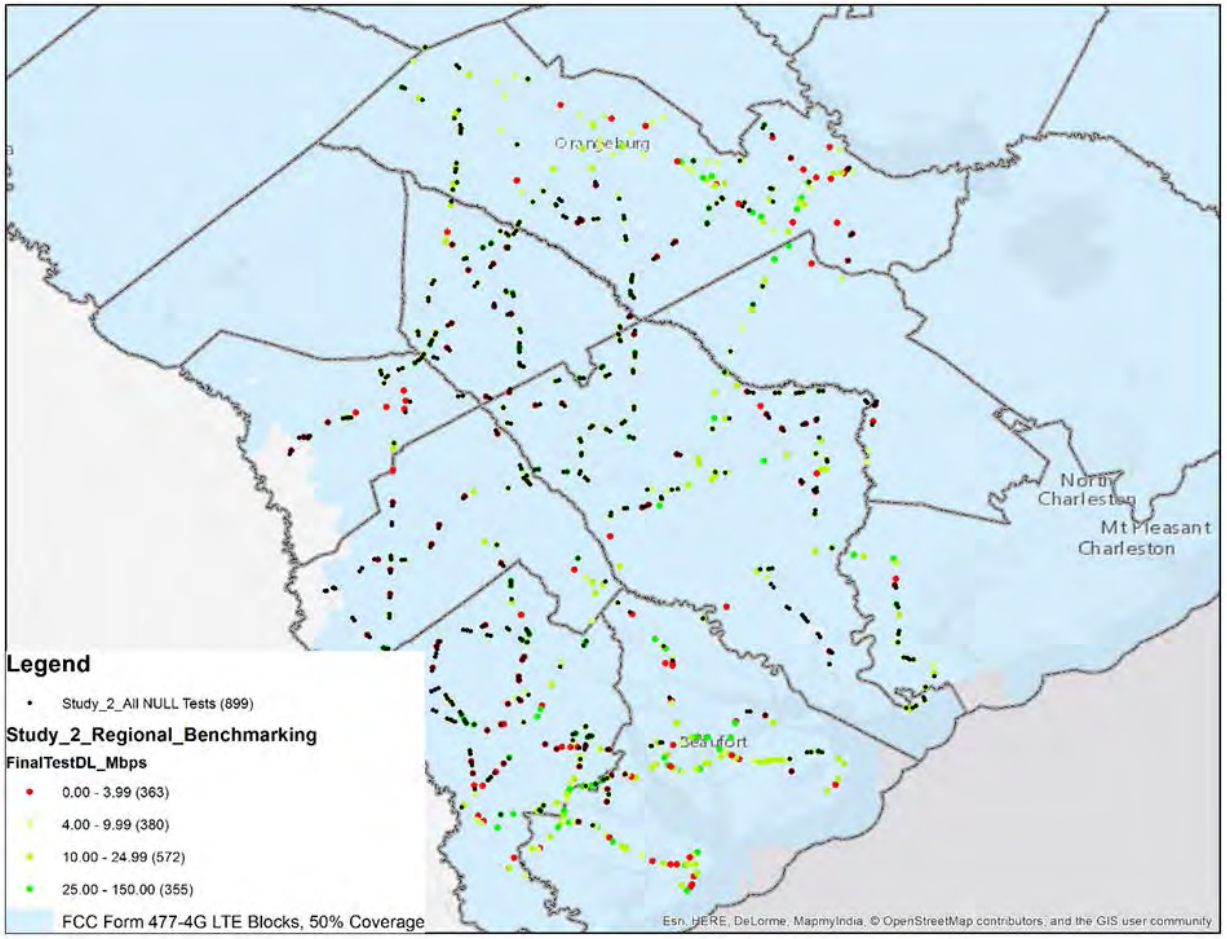

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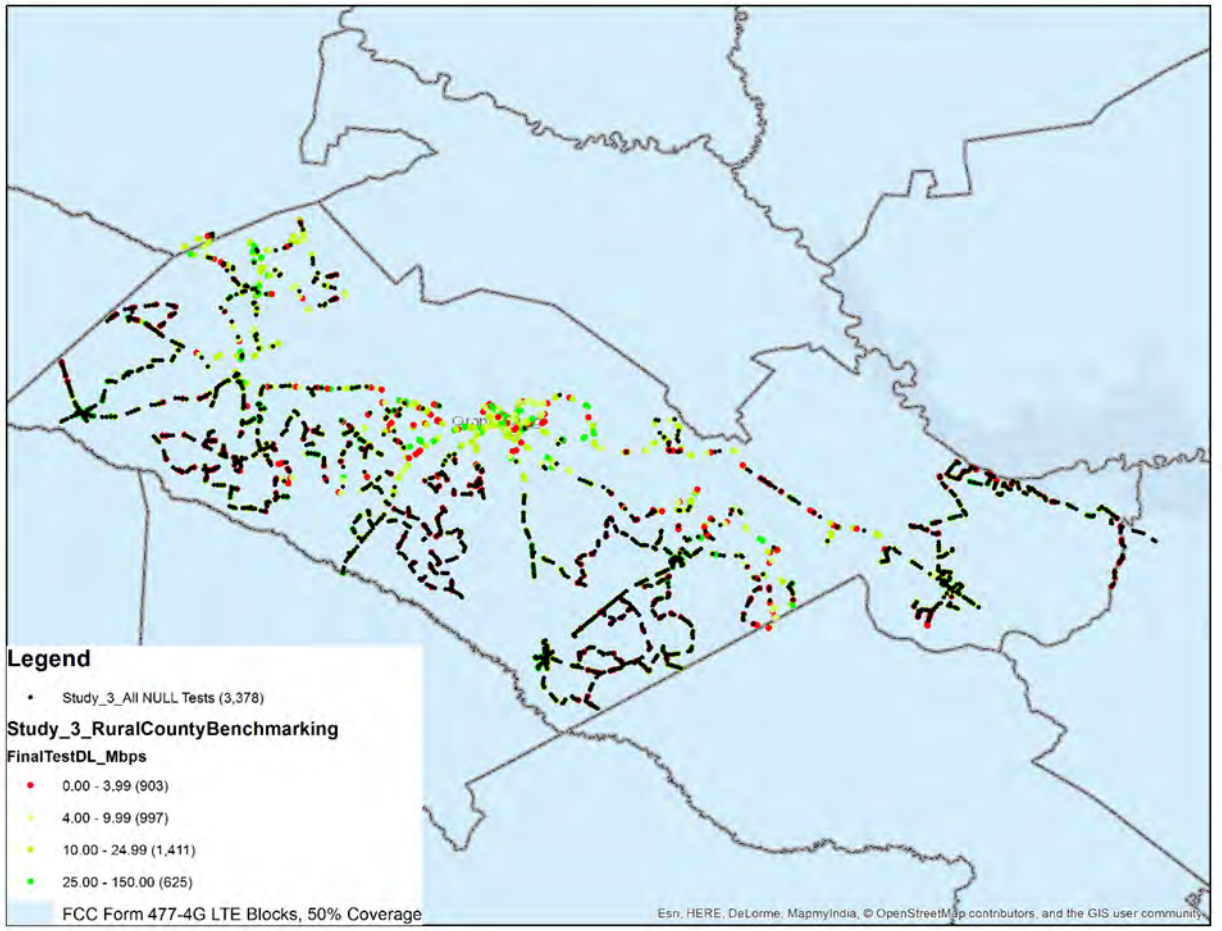

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Tested Speeds	Census Block Count
Presence of Tests <4Mbps	753
Total CB's w/ Download Tests	816

Figure 1 - CB Count by Download Speed Threshold for Study 3

Connection Success	Census Block Count
Presence of Tests w/ No Connection Success	515
Total CB's w/ Download Tests	816

Figure 2 - CB Count by Connection Success for Study 3

Orangeburg County - The drive testing team collected download speed tests in 816 Census Blocks in a five-day period in Orangeburg County. The Form 477 data, using the Actual Service Area approach, shows that there is coverage present in all of those Census Blocks. However, this benchmarking test measured speeds below 4Mbps in over 750 of those blocks. This accounts for 92% of all blocks with download tests for Study 3.

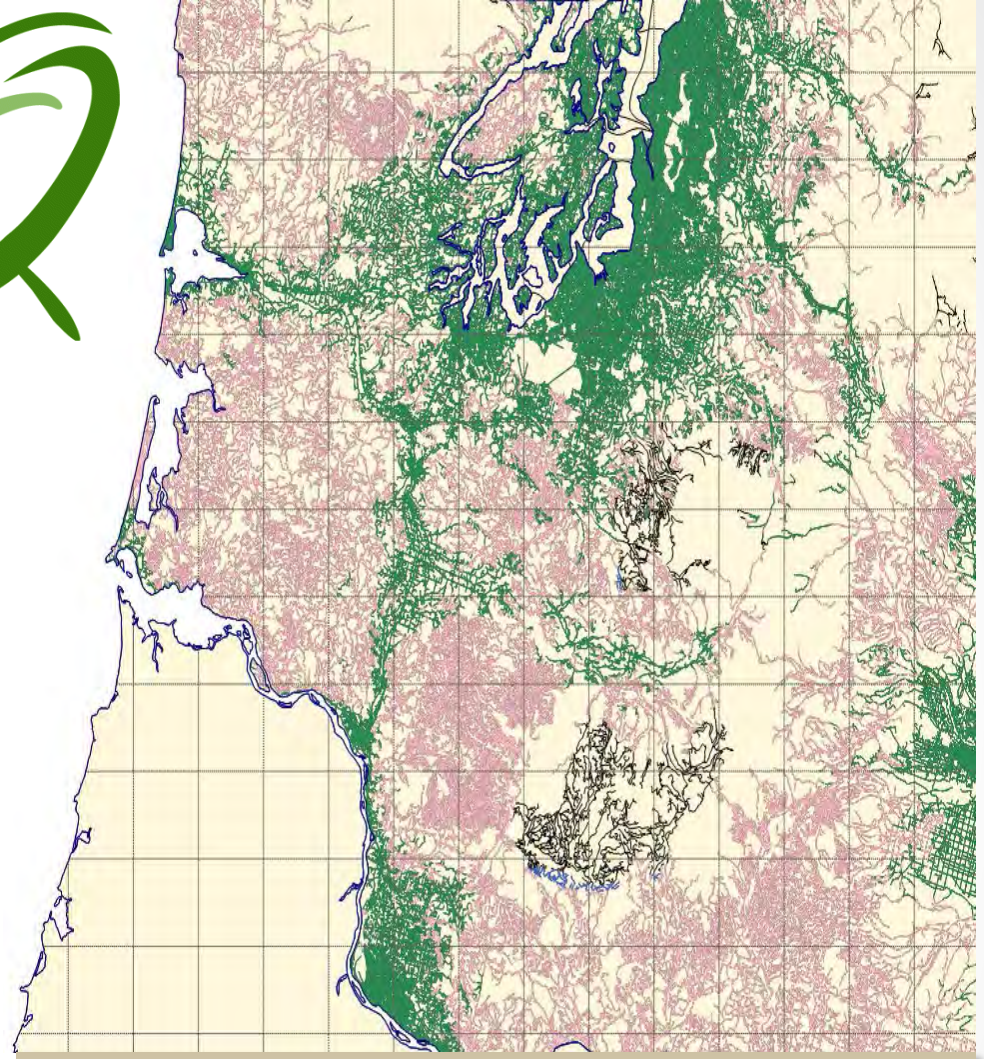
Questions not Answered in this Study

- While there is a better understanding of network metrics from inside a car, on roads, we did not measure indoor (in buildings and homes) coverage. **How would the results differ inside metropolitan, suburban, and rural structures?**
- Only network connection and data throughput were measured for all three studies. **Texts, voice, email and web/application use tasks were not measured.** Given the number of road miles and areas to cover, the test cycles did not allow for all these tests. **What would the results show us if the various tasks consumers regularly perform were measured?**
- **If speed tiers were made available by the FCC, how would those advertised speeds compare with the drive tested results?**
- While the areas of South Carolina were selected as a representative sample of population centers, roads and rural areas, **what would a larger, more diverse sample area show us? Could assumptions be made regarding nationwide service availability and reliability be made if a larger study were conducted?**

Who is CostQuest

CostQuest Associates

- Cincinnati – Bellevue
- Formed in 1999
- Internationally recognized as leading telecommunication network modeling, costing and profitability experts
  - Broadband and USF models: BAM used by FCC for NBP, CACM being used as national CAF/USF model, CPM California, CPM Hong Kong, BCPM, NUSC Australia, CostPro-Core New Zealand
  - RCN and Loop models: CostPro in use by carriers with operations in all 50 states, adopted and well received by commissions in all UNE and Tax proceedings
  - Wireless Costing: Wireless Models NTIA, CTIA, Wireless Carriers
  - Wireless Work: USAC Filings, Audits and Reviews, USAC/USF Workshops, GIS Analysis, Policy Support
  - Interconnection model: CostPro-Core in use by the New Zealand Commerce Commission to set rates
  - Profitability models: COMPASS, MAPS, ProfitMap, CPMS, and MIDAS – economic based contribution models over various business dimensions
- Global experience in developing, supporting regulatory and competitive practices



- Economic Network Modeling
- Mapping/GIS
- Regulatory Support
- Valuation/Costing
- Profitability
- Expert Testimony

CostQuest Associates

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